**Title: Binary Counter Circuit**

**Link to Outcomes:**

- **Problem Solving** While applying their knowledge of the binary number system, students will design and build a circuit that counts from zero to nine in binary. Problem solving skills are essential in debugging faulty circuits, as well as in extending the initial design (modifications, such as counting backwards, counting from 0-99, or starting to count from a preset value).

- **Communication** In order to develop the binary counter, students will work in pairs to allow for a high level of interaction in designing and debugging the circuit. Further, communication is encouraged between the teams who successfully complete the activity and those teams who may need assistance.

- **Reasoning** Students will apply reasoning skills to explain why the circuit operates as it does or to identify possible paths for troubleshooting a faulty circuit based on the level of the problem.

- **Arithmetic/ Algebra** Students will extend their understanding of arithmetic in base ten to the binary number system. This includes addition and multiplication, as well as decimals.

- **Number Relationships** Students will grasp the notion of "places" within various number systems as representing ascending powers of the base.

- **Patterns/ Relationships** Students will be able to deduce the algebraic laws of number systems for bases other than ten (10) and two (2) based on their understanding of the decimal and binary number systems.

**Brief Overview:**

The goal of this lesson is to design and build an electronic circuit that counts in binary from zero to nine. The students will combine their knowledge of number systems and basic digital electronics to complete this project. Once the basic requirement has been met, more advanced students are encouraged to enhance their circuits in several ways. These enhancements include, but are not limited, to the following:

- Cascading counters to make a 0-99 or 0-999 counter.
- Modifying the circuit, such that, it counts backwards.
- Modifying the circuit, such that, it starts counting at a preset value, rather than zero.
- Tuning the timer circuit to the frequency of one beat per second, representing a very basic clock.

- Building a 0-99 counter and tuning the timer to 0.1 seconds, representing a stopwatch that times events of under 10 seconds in duration. This may be activated/deactivated via a switch in the circuit.

**Grade/Level:**

This lesson is appropriate for students who have completed basic algebra. It is assumed that a basic overview of digital electronics is concurrently delivered to the students in order to assist them in the laboratory.

**Duration/Length:**

This lesson will require approximately two hours in the electronics laboratory. This assumes that students are already somewhat familiar with the lab equipment and procedures. It also assumes a basic understanding of digital electronics through several days of discussion and demonstrations in class.

**Prerequisite Knowledge:**

Prerequisites for this lesson include an understanding of the binary number system, understanding of basic digital electronics, and familiarity with the laboratory equipment and procedures.

**Objectives:**

- To apply and reinforce knowledge of the binary number system.
- To encourage creativity in expanding the project beyond the basic requirements, whereby students would construct cascaded counters (1-99, 1-999) and variations (counting backwards, or starting at a preset value).
- To encourage teamwork and cooperation in designing and troubleshooting circuits.
- To reinforce the basic principles of digital electronics through repeated exposure in the lab.
- To increase the students' proficiency in the laboratory.

**Materials/Resources/Printed Materials:**

- 555 IC (Integrated Circuit) and data sheets
- 74192 IC and data sheets
- Six 150 ohm resistors
- Five LEDs (Light Emitting Diodes)
- One 500,000 ohm potentiometer
- One 1 microfarad capacitor
- Breadboard
- Wire and wire stripper
- 5-volt power supply

**Development/Procedures:**

- Construct a timer circuit that outputs a square wave pulse train with the following components: 555 IC, 1microfarad capacitor, two 150 ohm resistors, one 500,000 ohm potentiometer and one LED. Connect pins 4 and 8 to 5-volts. Connect pins 4 and 7 with one 150 ohm resistor. Connect pins 6 and 7 with the 500,000 ohm potentiometer. Connect pins 2 and 6 directly together. Connect pins 2 and 1 with the 1 microfarad capacitor with the negative side of the capacitor connected to pin 1. Connect pin 1 to ground. Connect pin 3, the output, to the positive side of the LED. Connect the negative side of the LED to the 150 ohm resistor, and connect the other side of the 150 ohm resistor to ground. Verify that the circuit outputs a blinking LED. Verify that the blinking rate can be adjusted by varying the potentiometer.

- Construct a binary counter circuit with the following components: 74912 IC, four LEDs, and four 150 ohm resistors. Connect pins 16, 11, and 4 to 5-volts. Connect pins 14 and 8 to ground. Connect pin 7 to the positive side of the LED, the negative side of the LED to a 150 ohm resistor, and the other side of the resistor to ground. Connect to other three LEDs and resistors in the same fashion to pins 6, 2, and 3.

- Connect the timer circuit to the counter circuit by connecting pin 3 of the 555 IC to pin 5 of the 74192 IC. The square wave pulse train output of the timer circuit will set the rate of counting by the binary counter circuit. Verify that the counter circuit counts from 0 to 9 in binary at the rate determined by the counter circuit. Verify that the counting rate changes as the potentiometer is varied.

**Evaluation:**

Circulate around the lab and check on the progress of the students. Ensure that each student verifies that the counter circuit counts in binary from 0 to 9 correctly by having the student count in base 10 along with the circuit. Ensure that all students follow good breadboarding techniques.

**Extension/Follow Up**:

The counter circuit can be modified to count backwards from 9 to 0 by connecting pin 3 of the 555 IC to pin 4 of the 74192 IC and by connecting pin 5 of the 74192 IC to 5-volts.

Two counter circuits can be cascaded to create a 0 to 99 counter by using the carry-out feature of the 74192 IC. The carry-out pin is described in the 74192 IC data sheets.

The counter can be configured to begin counting at a preconfigured number. This feature is useful for creating a stopwatch, that begins counting at 60 (or 59) and counts down to zero. The preset pins are described in the 74192 IC data sheets.

**Authors:**

Houman Modarres
Newbridge Networks

Ted Tanaka
Newbridge Networks